PROCEEDINGS OF SCIENCE

Searches for sleptons with the ATLAS detector

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Supersymmetry is one of the most popular extensions of the Standard Model, but no evidence supporting its validity has been observed at LHC up to date. The second period of data taking at the LHC at 13 TeV of center of mass energy ($\sqrt{s}$), Run-2, started in 2015 and provides an important test field for the search of beyond the Standard Model physics. In particular, the production of supersymmetric electroweak particles, such as sleptons, neutralinos and charginos, could be a promising probe for SUSY signals at LHC, despite the lower cross sections if compared to the ones of the strong production processes. This proceeding summarizes some of the most recent ATLAS results obtained from the searches for sleptons, both produced directly or via $\tilde{\chi}_1^{\pm}$ or $\tilde{\chi}_2^0$ decays, with 36.1 fb^{-1} of data collected in 2015-2016.

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1. Introduction

Supersymmetry (SUSY) [1] is a theoretical extension to the Standard Model (SM) which provides a solution to the hierarchy problem by predicting the existence of a new fermion/boson supersymmetric partner for each boson/fermion in the SM. The superpartners of the SM leptons, the SM Higgs and the SM electroweak gauge bosons are sleptons, higgsinos, winos and bino, respectively. Higgsinos, winos and bino, collectively known as electroweakinos, mix to form chargino ($\tilde{\chi}_i^{\pm}, i = 1,2$) and neutralino ($\tilde{\chi}_j^0, j = 1,2,3,4$) mass eigenstates (ordered by increasing values of their mass). If coloured sparticles, gluinos and squarks, have masses much heavier than electroweakinos, then SUSY production at the LHC would be dominated by direct electroweak production. The latest ATLAS limits on squark and gluino production [2] extend well beyond the TeV scale, thus making electroweak production of sparticles a promising probe of SUSY at the LHC.

The analyses presented here focus on the searches for the electroweak production of slepton pairs, direct or from chargino or neutralino decays, in final states with leptons: electrons (e), muons (μ) or hadronically decaying taus (τ). Sleptons are searched for both in R-parity conserving [3] (RPC) and in R-parity violating (RPV) scenarios. All searches have been performed using 36.1 fb^{-1} of data collected in 2015-2016 at $\sqrt{s}$ = 13 TeV by the ATLAS detector [4]. The results are interpreted in the context of simplified models [5], where the masses of the relevant sparticles are the only free parameters, and with branching ratios (BR) set to 100% for the searched decays.

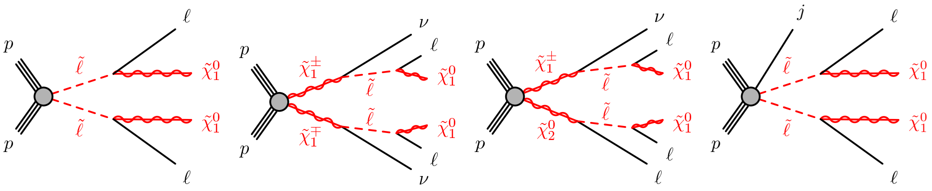
2. Search strategy

The background estimation method as well as the interpretation of the results in the context of the models under study are similar for the various SUSY analyses. The main irreducible backgrounds from the SM processes, i.e. with prompt leptons and genuine missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$) from neutrinos, are estimated via partially data-driven techniques, normalizing Monte Carlo (MC) predictions to data in control regions (CRs) and extrapolating the normalization factors to the regions with enhanced signal (signal regions, SRs). CRs are enriched in the background process of interest and kinematically close, but orthogonal, to the SRs. Normalization factors are validated in validation regions (VRs) with kinematic requirements similar to the SRs ones but with smaller expected signal-to-background ratios. The contributions from rarer background processes are directly taken from MC. The reducible backgrounds contain, e.g., one or more "fake" or non-prompt (FNP) leptons and are estimated using fully data-driven methods. If no significant excess is observed in data above the expected SM background in the SRs, limits are computed at 95% confidence level (CL) within the HistFitter framework [6] using the profile-likelihood-ratio test statistic.

3. Search in final states with 2 or 3 leptons

Different classes of models involving slepton production were tested: (a) direct $\tilde{\ell}\tilde{\ell}$ production [7]; (b) direct $\tilde{\chi}_1^{+}\tilde{\chi}_1^{-}$ production where sleptons are assumed to be light and accessible in the sparticle decay chain [7]; (c) direct $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production and decay via intermediate $\tilde{\ell}_L$ or $\tilde{\nu}_L$ [7]; (d) direct $\tilde{\ell}\tilde{\ell}$ production in a compressed scenario [8], where sleptons have masses just above the mass of a pure bino LSP. Diagrams of the considered processes are shown in Fig. 1.

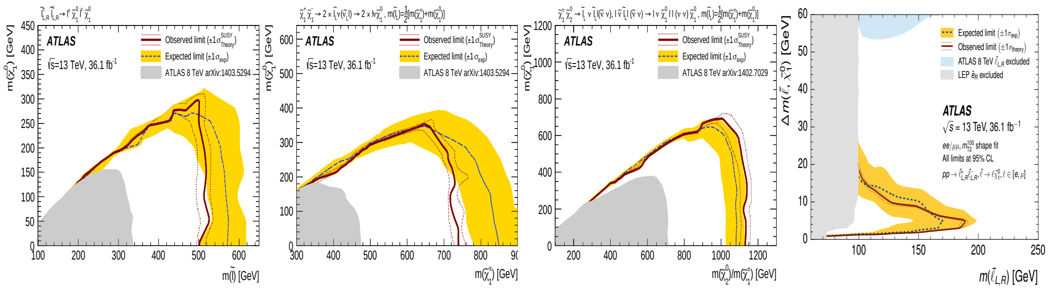
The experimental signatures of the processes (a), (b) and (c) are characterized by a large $E_{\mathrm{T}}^{\mathrm{miss}}$ and no jet in the final state. Exactly two isolated, opposite sign (OS), high $p_{\mathrm{T}}^{\ell 1,\ell 2}$ (larger than 25, 20 GeV) e and/or μ are requested to target (a) and (b) (2ℓ+0jets channel), while exactly three leptons (e or μ) are requested to search for process (c) (3ℓ channel). In all cases, the invariant mass $m_{\ell\ell}$ of any OS lepton pair with same flavour (SFOS) is requested to be far away from the Z mass peak, in order to suppress the dominant Z or WZ (for the 3ℓ channel) backgrounds. SFOS pairs also arise from process (d), but in this case the final state leptons,e or μ, are expected to be soft. Moreover,



(a) (b) (c) (d)

Figure 1: SUSY processes considered for the slepton searches in final states with 2 or 3 leptons.

to target process (d) a large $E_{\mathrm{T}}^{\mathrm{miss}}$ (> 200 GeV) from the two LSPs recoiling against an initial-state radiation (ISR) leading jet (with p_{T} > 100 GeV) is requested. The SR definition relies, for (a) and (b), on the dilepton stransverse mass m_{T2} [9, 10], a kinematic variable used to bound the masses of a pair of particles that are presumed to have each decayed into one visible and one invisible particle. For $t\bar{t}$ or WW decays, in an ideal detector with perfect momentum resolution, m_{T2} has a kinematic endpoint at the W mass, then signal events are required to have higher m_{T2}. For process (c), the invariant mass of the SFOS pair, $m_{\ell\ell}$, and the p_{T} value of the third leading lepton $p_{\mathrm{T}}^{\ell 3}$ are exploited to define the SRs, while for process (d) the SRs are defined by binning in dilepton m_{T2}^{100}, requested to be more than 100 GeV (the superscript indicates the value chosen for the LSP masses in computing m_{T2}).



(a) (b) (c) (d)

Figure 2: 95% CL exclusion limits on SUSY simplified models for (a) slepton-pair production, (b) chargino-pair production and (c) chargino–neutralino production with slepton-mediated decays [7], and (d) slepton-pair production in the compressed scenario [8].

For the 2ℓ+0jets channel the dominant backgrounds are the SM diboson production and dileptonic $t\bar{t}$ and Wt events. For the 3ℓ channel the irreducible background is dominated by the SM WZ processes. For sleptons in the compressed scenario the FNP background tends to be dominant especially at low m_{T2}^{100} values. Since no significant excess above the SM expectation is observed in all channels, exclusion limits for the scenarios (a)-(d) are set at 95% CL (Fig. 2).

4. Search in final states with at least 4 leptons

A search for SUSY partners of left-handed leptons was performed in final states with at least four isolated, charged leptons (e, μ or up to two hadronically decaying τ) [11]. Simplified models with RPC slepton pair production followed by RPV decays of the LSP in $\ell\ell\nu$ with a 100% BR [12], as shown in Fig. 3 (left), were tested. In these models, sleptons are supposed to be the Next-Lightest-SUSY-Particles (NLSP). Events with four or more signal leptons are selected and classified according to the number of e or μ and τ, and a Z veto is applied using the mass $m_{\ell\ell}$ of any SFOS lepton pair combination in the event. Finally, the SR definition is based on the effective mass of the event m_{eff}, defined as the scalar sum of $E_{\mathrm{T}}^{\mathrm{miss}}$, the lepton p_{T} and the p_{T} of all jets with transverse momentum larger than 40 GeV. No significant excess above the SM expectation is observed in data, and the exclusion contour for the RPV $\tilde{\ell}_L/\tilde{\nu}$ NLSP model is shown in Fig. 3 (right) for two different scenarios (depending on λ_{ijk} RPV couplings).

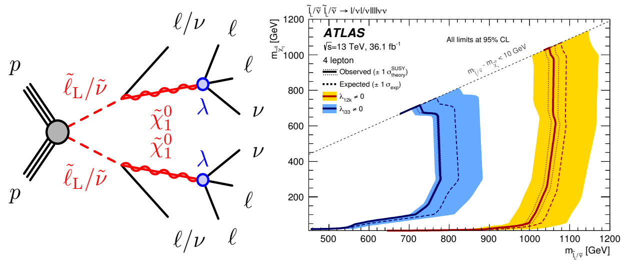


Figure 3: SUSY models considered for the slepton searches in final states with at least 4 leptons (left). 95% CL exclusion limits on slepton/sneutrino NLSP pair production with RPV $\tilde{\chi}_1^0$ decays via the couplings λ_{12k}, or λ_{i33} where $i,k \in 1,2$ (right) [11].

5. Search in final states with τ leptons

Processes involving τ leptons in the final state are searched for in models in which $\tilde{\chi}_1^+\tilde{\chi}_1^-$ or $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ are produced and decay via staus as in Fig. 4 (a) and (b) [13]. $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ are assumed to be mass-degenerate, as the stau and τ sneutrino, the lightest neutralino to be purely bino and the stau mass eigenstate to be purely $\tilde{\tau}_L$. Signal events are characterised by at least two hadronically decaying OS taus and large $E_{\mathrm{T}}^{\mathrm{miss}}$. The SR definition vetoes b-tagged jets and Z bosons in the event, and is based on $E_{\mathrm{T}}^{\mathrm{miss}}$ and on the τ pair stransverse mass m_{T2}. No excess is found in neither of the SRs and the exclusion limits in the relevant mass planes are shown in Fig. 4 (c) and (d).

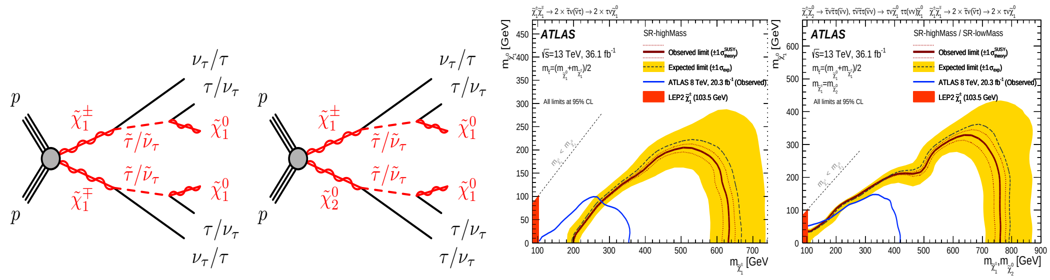


Figure 4: (a) and (b) SUSY processes considered for the searches involving staus. 95% CL exclusion contours for simplified models with $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (c) and $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ (d) decaying in taus via staus [13].

6. Conclusion

Several searches for slepton production, direct or from gaugino decay, have been performed in ATLAS using 36.1 fb^{-1} of collected pp collision data at $\sqrt{s} = 13$ TeV. No significant excess above the Standard Model predictions has been observed, and 95% CL exclusion limits on the SUSY particle masses have been set, significantly extending the corresponding Run-1 results.

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